How Strong Is Your Tinder Game? Two-Sided Search in Swipe-Based Dating Applications

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Abstract

In today's love market, swipe-based dating apps have a well-established presence, but novel platform features can add significant complexities to the user's search problem in ways that have not been studied in existing literature. This paper formulates a game-theoretic model of two-sided search within swipe-based dating apps, along with an appropriately refined notion of equilibrium. Using numerical methods, I approximate equilibria at the steady-state and perform comparative statics on various model parameters to replicate and explain stylized facts observed in aggregate Tinder data. Finally, agent-based simulations are used to analyse off-path dynamics and discuss how exogenous platform features (such as the matching algorithm and the swiping caps) can be set in a socially-efficient manner.

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1 Introduction

It is widely considered that the search for love is an intricate and complex social phenomenon, and in today's world, swipe-based dating applications seem to only make it trickier. These platforms, best exemplified by Tinder or Bumbble, provide a gameified way of browsing through potential romantic partners by swiping through a stack of suggestions to indicate likes or dislikes, one profile at a time. In the search and matching literature, these fall under the category of decentralized two-sided matching markets with online search (Kanoria and Saban, 2021), emphasising the fact that *a)* both sides of the market are comprised of rational agents, *b)* matches only occur given a double coincidence of wants, and *c)* romantic suggestions are presented in a *sequential* manner to users. These apps thus differ widely from traditional dating sites where users are centrally and statically matched (such as ...), but have come to dominate the modern love market, with Tinder boasting XXX million users as of 2021 and YYY million paid subscribers.

From a theoretical standpoint, these platforms introduce many additional complexities that, due to their novelty, have been sparsely studied in the economics literature, with these falling into two categories: those arising from platform features and those arising from the intrinsic nature of the problem. The first of these refers to platform-specific factors such as suggestion algorithms, matching technologies, swiping caps, and asynchronicity, which are often determined exogenously and pose significant constraints to the way utility-maximizing agents strategise their search process. On the other hand, the generalized problem of search is inherently complex as it involves a dynamic game of incomplete information where, even though the stage interaction is simple, its repetition demands consideration of

Overall, the prevalence of these swipe-based dating apps in modern social interactions, the theoretical complexities they induce, and the largely understudied nature motivated this dissertation. Although many different questions can be asked regarding these platforms, answering these requires a fundamental understanding of how users make decisions in these platforms: to put it simply, *when should a user swipe right?*. This paper will explore the above question in the setting of a swipe-based dating platform where agents on both

formulating a game-theoretic model of two-sided search within these platforms along with a corresponding definition of equilibrium. Using numerical methods, I approximate the steady-state equilibria and perform comparative statics

Points to discuss on introduction

- What is Tinder? (brief)
  - When was it started?
  - What is swiping?
  - How popular it is?
- Why does Tinder pose an interesting economic problem?
  - Stage interaction
  - Platform features: budgets, observability, directed search, asynchronicity
  - Repeated games: curse of dimensionality, beliefs and meta-beliefs
- What and how does this paper study?

- Model of two-sided search with strategic considerations
- Equilibrium refinement, computation, and analysis
- Planner considerations on directed search and budget setting

- What does this paper contribute?
  - First model to address budgeted search in Tinder?
  - First model to combine idiosyncracy and pizzaz
  - Case study for the use of computational techniques in

1.1 Related Work

- Searching and Matching
  - Gale and Shapley (1962), Roth and Sotomayor (1992)
  - Two-sided: Burdett and Wright (1998), Chade (2006), Smith, Adachi
  - **Does not consider budgets**
    - ... important as this is a way for planners to influence outcomes
- Mean-Field Game Theory: Iyer et al. (2014), Gummadi et al. (2013), Jovanovic and Rosenthal (1988)
  - No models on MFG for Tinder
- Modern Dating Apps: Olmeda (2021), Kanoria and Saban (2021)
  - Not models where behaviour is derived from rational utility-maximizing assumptions

2 Theoretical Model

2.1 Setup

Consider the two-sided search market formed by the Tinder platform with both male and female agents looking for potential partners. For ease of exposition, we assume that this market is heteronormative such that male agents search exclusively for female agents only and vice-versa. Time is discrete and indexed $t = 0, 1, ...$ over an infinite horizon. At every time period, agents from each sex are paired up and presented a suggested partner from the opposite side of the market. To their knowledge, this happens randomly in an unknown manner. Agents can then choose whether to swipe left (dislike) or right (like) on their suggestion, yielding an action space of $\mathcal{A}_m = \mathcal{A}_w = \{\text{left, right}\}$. If both agents swipe right on one another, they are said to have *matched* and both receive a matching payoff, however, if either agent swipes left, they both receive a payoff of zero. Importantly, the suggested partner's action is only *observable* if one swipes right.

Each agent has an attractiveness type $\theta \in \Theta := [0, 1]$ which is unknown to them but observable to their suggestion, and it is common knowledge that this is the case. Contingent on matching with a suggestion of attractiveness θ, a user earns a matching payoff of $u(\theta)$, where $u(\cdot)$ is a strictly increasing, concave function that satisfies $u(0) = 0$.

This last property stems from the fact that, in Tinder, users are allowed to unmatch with each other, thus implying that matching with the least attractive individual on the other side of the market is weakly preferred to the payoff from not matching. Given the above, Tinder makes right-swiping costly by placing a cap on the total number of right swipes for each user. We refer to the total number of right-swipes a user has left as its *budget*, b_t, which evolves dynamically according to the law of motion:

$$b_{t+1} = b_t - a_t$$

where the starting budgets for each sex, B_m and B_w, are determined exogenously. The budget sets for men and women are thus defined by $\mathcal{B}_i = \{b \in \mathbb{Z} : 0 \leq b \geq B_i\}$, with $i = m, w$ respectively.

Each period, λ_m new men and λ_w new women enter the platform, with their attractiveness drawn i.i.d from distributions with c.d.f's F_m and F_w, respectively. Importantly, agents depart from the platform in one of two ways: they can leave *endogenously*, if they expend their swiping budget, or *exogenously* with probability $(1 - \delta)$. This admits to the interpretation of a geometrically distributed lifetime parametrized by δ, and implies that users use this as a discounting factor for future payments. At any given time t, the masses of men and women on Tinder are denoted by N_m^t and N_w^t, respectively. Given sample spaces $\Theta \times \mathcal{B}_m$ and $\Theta \times \mathcal{B}_w$, let $\mathbb{P}_m$ and $\mathbb{P}_w$ be the probability measures over the corresponding σ-algebras. Furthermore, let $M^t, W^t : \Theta \times \mathcal{B}_i \to [0, 1], \quad i = m, w$ be the endogenous mixed distributions over agents (male and female, respectively) in the platform. These are endogenously determined since the flow of agents into lower budget levels and eventually out of the platform depends on their swiping decisions, determined endogenously through a search process. Finally, since gender imbalances mean that not everyone might receive a suggestion, the question remains of how to decide which agents on the long side of the market get paired up. Since Tinder is fair and efficient platform, we model a frictionless matching technology and denote market tightness, ie. the probability of receiving a suggestion on either side, by:

$$\tau_m^t = \min\{\frac{N_w^t}{N_m^t}, 1\}, \ \tau_w = \frac{N_m^t}{N_w^t}\tau_m^t$$

Given the above, a number of simplifications to the explored setting are possible.

- 1. An agent's decision on any given time period depends fundamentally on the attractiveness of the suggested partner and their own budget

I restrict attention to stationary Markov strategies, defined by $\sigma_m : \Theta \times \mathcal{B}_m \to \Delta\mathcal{A}_m$ for men and $\sigma_w : \Theta \times \mathcal{B}_w \to \Delta\mathcal{A}_w$ for women, where ΔS is used to denote the probability simplex over set S.

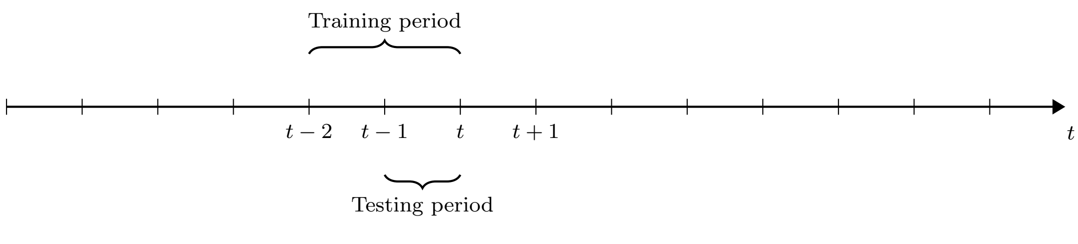

Figure 1: Timeline of events within each time period

2.2 The Dating Market

- Entry flows
- Leaves (including geometric lifetime)
- Masses
- Distribution
- Steady State

2.3 The Search Problem

- Present case for women, then say case for men follows
- Condition on male strategy and steady state
- Present Ex-interim utility maximization
  - Show it reduces to a constant
- Present sequence problem
- Derive Bellman equation
- Prove uniqueness of value function and solution
- Derive solution

3 Equilibrium

3.1 Steady-State Equilibrium

- Define and explain concept of SSE
- Explain computation via least-squares
- Explain main properties (eg. ESS & uniqueness)

3.2 Comparative Statics

- Present CS on individual factors and explain intuitively
- These include: patience, risk aversion, distributions
- Present case of gender disbalance... why is it that men always swipe right?
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4 Agent-Based Simulations

4.1 Convergence and Dynamics

- Check Mass convergence
- Check distribution convergence
- Relate to ESS
- What about Dynamics??? BR

4.2 Directed Search

- try page rank
- try elo rating
- try v simple RW algo
- Do any of these converge onto GS (note... define gale shapley mathcings)?

4.3 Social Efficiency

5 Conclusion

In this chapter we shall do a reference to an entry in the bibliography, `bibliography.bib`.

What we know of the invention of the flux capacitor is that Dr. Emmett Brown thought of this when hanging a clock in the bathroom. He was standing on his porcelain sink and slipped because it was wet, the resulting hit on the head was apparently a cause to this invention Brown (1955).

5.1 Future Work

The corresponding sketch made on this day has been attached in appendix B.

References

Brown, E. (1955). The creation of the flux capacitor. .

Burdett, K. and Wright, R. (1998). Two-sided search with nontransferable utility. *Review of Economic Dynamics*, 1(1):220–245.

Chade, H. (2006). Matching with noise and the acceptance curse. *Journal of Economic Theory*, 129(1):81–113.

Gale, D. and Shapley, L. S. (1962). College admissions and the stability of marriage. *The American Mathematical Monthly*, 69(1):9–15.

Gummadi, R., Key, P., and Proutiere, A. (2013). Optimal bidding strategies and equilibria in dynamic auctions with budget constraints. *Available at SSRN 2066175*.

Iyer, K., Johari, R., and Sundararajan, M. (2014). Mean field equilibria of dynamic auctions with learning. *Management Science*, 60(12):2949–2970.

Jovanovic, B. and Rosenthal, R. W. (1988). Anonymous sequential games. *Journal of Mathematical Economics*, 17(1):77–87.

Kanoria, Y. and Saban, D. (2021). Facilitating the search for partners on matching platforms. *Management Science*.

Olmeda, F. (2021). Towards a statistical physics of dating apps. *arXiv preprint arXiv:2107.14076*.

Roth, A. E. and Sotomayor, M. (1992). Two-sided matching. *Handbook of game theory with economic applications*, 1:485–541.

A Uniqueness and Existence of Search Problem

B Notation

- Male types μ
- Female types ω
- Strategies $s = (s_m, s_w)$
- CDF's $M(\mu, b)$, $W(\omega, b)$
- Densities $m(\mu, b)$, $w(\omega, b)$
- Discount δ
- Population CDF's F_m, F_w
- Masses N_m, N_w
- Entry Flows λ_m, λ_w
- Tightness $\tau = \min\{\frac{N_w}{N_m}, 1\}$
- Effective discount α